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The Spectrum of β Lyræ, as observed at Stonyhurst College Observatory in 1895. By the Rev. Walter Sidgreaves, S.J.

The collection of photographic spectra of *β Lyræ*, obtained with the light-power of the Perry memorial objective, consists of over 100 plates. The series was commenced in the early part of May and finished in October. During these months all other night work was considered of secondary importance. Particular attention was given to the night preceding the chief minimum, and we have thirteen plates belonging to the last day of the period, or within twenty-two hours of the minimum. Three of these cover the minimum passage and belong both to the last and to the first day of the period.

It was at first intended to make use of only three plates for each of the thirteen days, as mentioned in our report of the Observatory in the *Monthly Notices* of 1896 February. But as the micrometer work upon the plates progressed, it became evident that nearly all the plates should be used; for it was found that some details were seen on plates noted as inferior, better than on other more perfect-looking photographs. The total number of plates carefully examined is eighty-six. Some of these will be found to occupy two places in the appended catalogues of wave-lengths. In these cases half of the trailed spectrum belongs to one, and half to the following day of the light period, the whole trail being long enough to represent two separate exposures.

The slitless spectrograph employed for the series has been already fully described, partly in the *Memoirs*, vol. li, and partly in the *Monthly Notices*, vol. lvi. It is the spectrograph which was used for the *Nova* of 1892, with the alteration mentioned in the report of 1896 February. Great attention was given to this alteration, and we are largely indebted to Mr. Hilger for the expeditious way in which he helped the successive steps by which we finally arrived at the true configuration and relative densities of the component glasses for bringing the rays between D and H parallel on to the prism.

The greater stability of the instrument, owing to this alteration, has proved to be a great gain. The concave collimator having to take the cone of light before it arrives at the focal plane of the object glass, we have, in place of a long appendage to the eye end of the telescope tube, a short compact spectrograph fitted into a massive metal holder firmly screwed up in the position of an ordinary eye-piece. Its behaviour in different positions of the telescope is shown by the following scale readings for the prominent lines in the bright stars :—

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	Arcturus. Mm.	α Persei. Mm.	Capella. Mm.
D	84·65	84·66	84·65
F	79·55	79·55	79·55
G′	74·63	74·63	74·63
h	71·26	71·26	71·26
H	68·86	68·88	68·86

This appears to be as accurate as can be expected in so short a length as 15·8 mm. from D to H.

The first measurements were nearly complete at the end of 1895, but the full discussion of the series, allowing for considerable and unavoidable interruptions, has occupied a much longer time than was anticipated.

At the commencement of the work an attempt was made to show every detail of each plate on square ruled paper, and the result from fourteen plates charted in this way was an average of sixty groups of lines. But the greater number of these were too feeble to give any hope of tracing their variations with reliable accuracy; and it was decided to confine our attention to the more prominent ones. Thirteen groups were then selected for careful measurement, and the rest were left to the general remarks of the observer.

An inspection of the tables of figures will show that everything has been entered to enable the reader to form his own conclusions about the final table of mean wave-lengths, and the accompanying map of the selected lines for each day of the period. The plates are entered in the order of their time intervals from the preceding chief minimum, and their absolute dates are written in the last column, together with a note of their photographic excellence, g. meaning good, and v. very. The figures are tenth metres, and the small letters written over them* note the degree of uncertainty about them. A dash, in place of a number, explained at the foot of the table as inconclusive, means that the condition of the line, owing to a local weakness or blemish on the plate, could not be certified. It should further be observed, with reference to the note "probable," that the lines marked thus may be prudently accepted as certain: the distinction between a certain and a probable line being that the latter admits, of itself, the interpretation of contrast-effect, and is decided by its appearance on other plates in which this interpretation is inadmissible.

All the positions quoted in the tables and on the map are relative to that of the absorption component of H_γ, which has been adopted for the fiducial point of the curve-scale, at λ 4340. On the light-period map are shown only those lines whose changes could be followed with certainty. The complete spectrum of the star is given in addition as obtained from two selected plates, one near the primary, the other near the secondary minimum.

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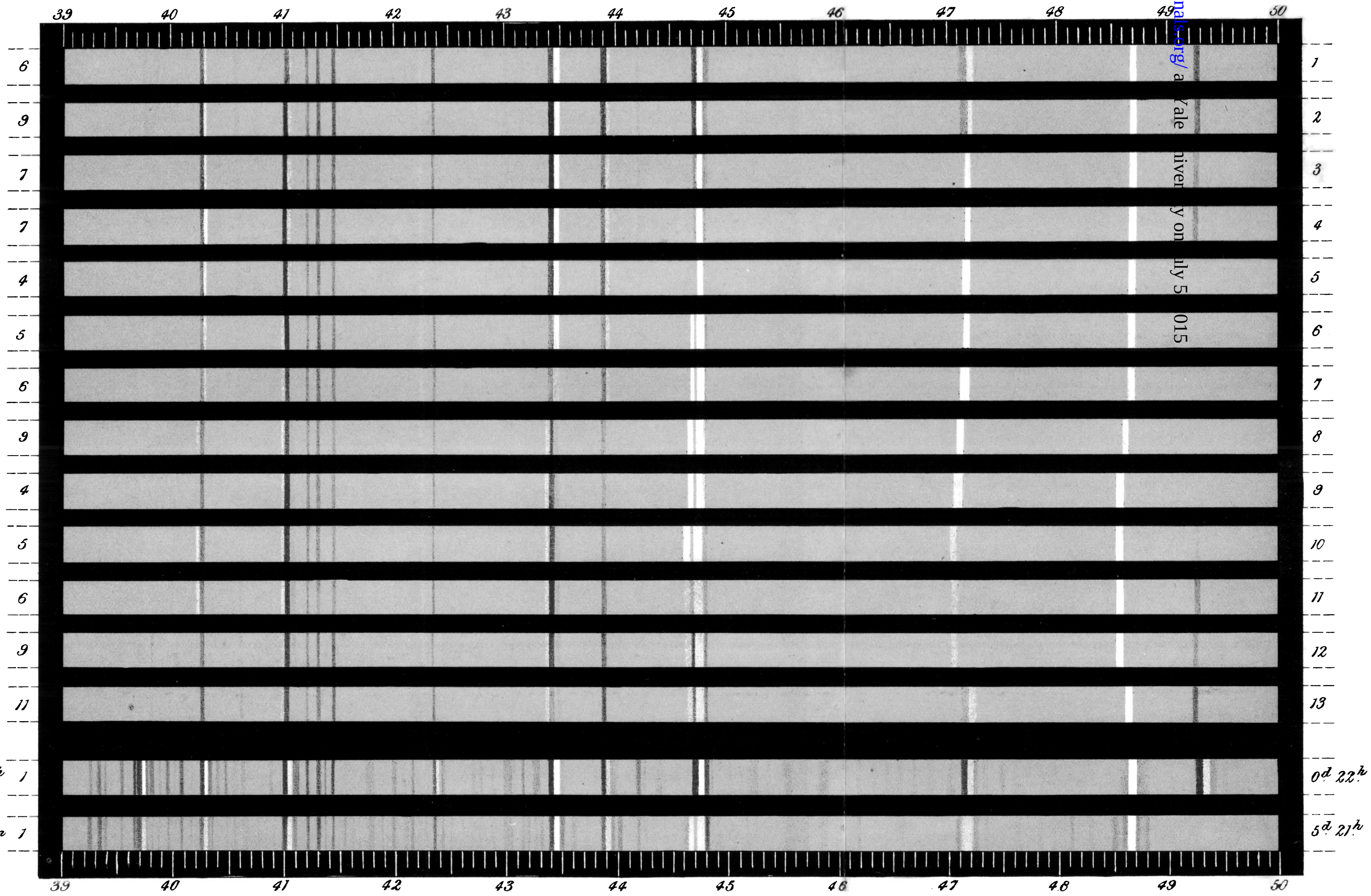
* p. for probable, and s. for suspected.


9m 29d 8h 1
m4d 7h 25m 1
0d 22h
5d 21h

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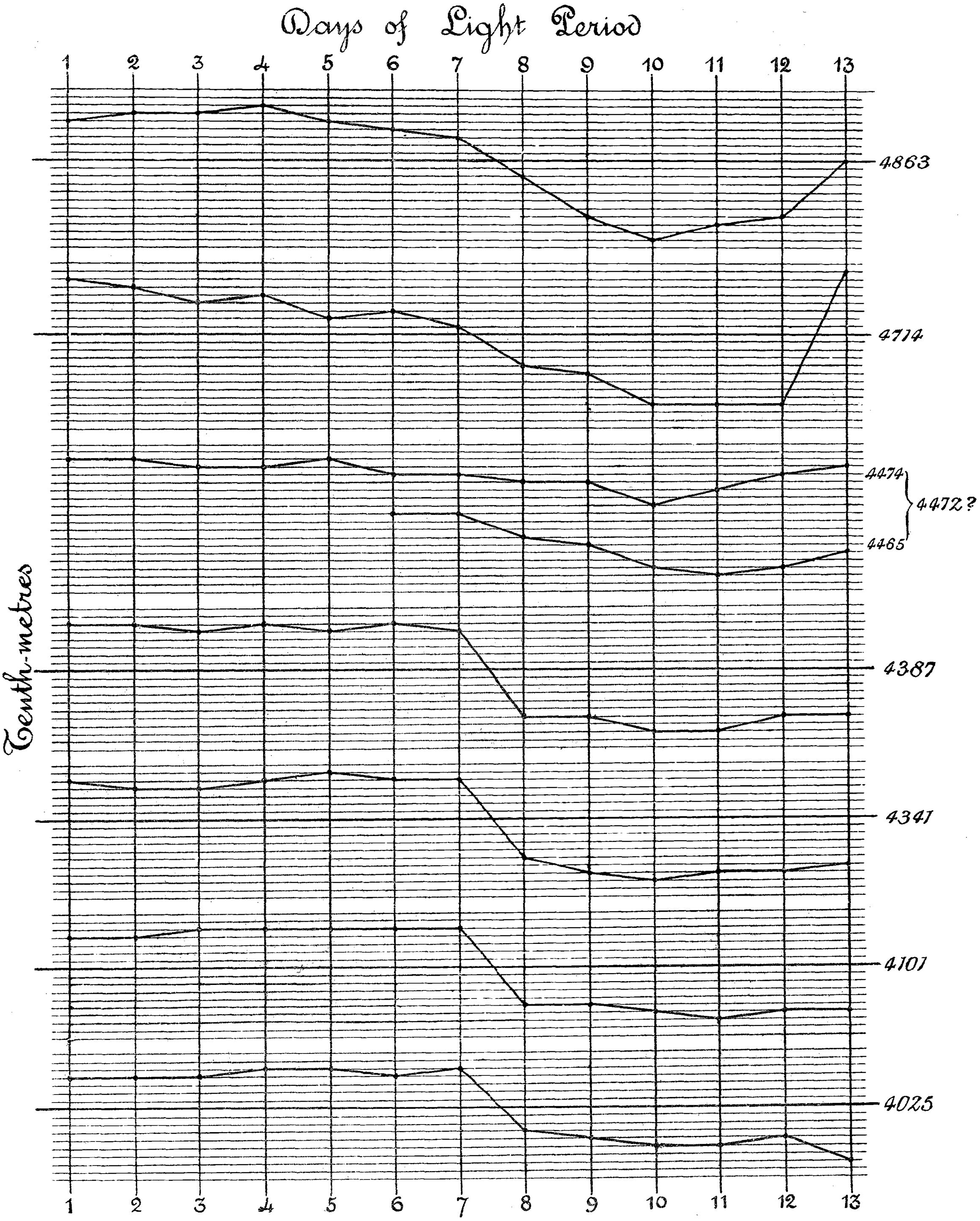

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The table of mean wave-lengths for each day shows considerable changes in the positions of the radiation lines, faithfully following the light period, while the absorption lines remain quite constant; and these mean positions are found to suffer nothing when the tables of details (pp. 522–9) are consulted. These show even more clearly that the positions of all the lines throughout the spectrum remain practically constant during the first four days after the chief minimum. On the fifth and sixth days there is a suspicion of change setting in, which becomes quite pronounced on the seventh day. The radiation lines are shifting towards the violet end of the spectrum and crossing their mean position shortly after the second minimum. On the eighth and ninth days, the wave-lengths are rapidly shortening, and reach their lowest measures on the tenth day, which is that of the second maximum. These changes are shown on the map (Plate 16)* in striking contrast with the fixed positions of the absorption lines.

The changes of the bright lines are further plotted from day to day of the light period in Plate 17, and the unsmoothed curves show, in addition to a general uniformity of all the lines, some noteworthy differences. The more abrupt shortenings of the four smaller wave-lengths between the seventh and eighth days, may be due to a greater width of these lines, which would have the effect of increasing the difference between the apparent and real centres of the lines; a difference which would be greatest at this phase of the curve when the bright line was beginning to appear on the violet side of its overlapping dark companion. The effect of superposition in concealing the real centre of the bright line has been studied by Belopolsky in H_β, and by Vogel in H_ζ; and both observers have come to the same conclusion—that the apparent doubling of the bright lines is to be attributed to the dark line cutting out the centre of the bright line; and that when the bright line is seen only on one side of the dark line, its apparent centre cannot be accepted for the true position of the line in an estimate of radial velocity; and the real centre cannot be ascertained because a constant width of the line is an inadmissible postulate.

If we could have plotted the real centres of these bright lines, the curves would have exhibited a much closer agreement with Professor Vogel's conclusion, that "only small changes, undoubtedly standing in a certain relation to the periodic variations of the star, can be observed in the relative positions of the bright and dark lines." † The curve for line 447 is an illustration of this effect. If the red side bright line ‡ had faded out when that at the violet side § began to appear, the curve would have been of the same steep form as the rest. This consideration suggested the probability that the pair of bright lines in the latter half of the light period might be parts of the same radiation; the position of

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* See also pp. 530–1.

† A and A–P, 1894 May, p. 362.

‡ The radiation of group 4.

§ The radiation of group 5.

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its true centre for each day would be given by the mean of the pair of figures for that day; and if we could, in a similar manner, point the true centres of the line in the first half of the period, the curve would be nearly of the form plotted for λ 4474, and the resulting indication of change of radial velocities would become comparatively small. This account of the pair of bright lines is in accord with Mr. McClean's recent explanation, that "the curious effect of displacement and doubling seen in the Helium line at w.l. 4472 appears to be due to the alternate obscuration of this line and the adjacent iron (?) line at w.l. 4482, by the shift of the corresponding diffuse emission Helium line at w.l. 4472"; * but we have no division of the bright line by the dark line 448 shown on our plates. It is more closely the same as Belopolsky's explanation of H_β†, and Vogel's H_ζ, &c.; and it seems to point out the treatment of the other radiations, needed for trimming our curves to a satisfactory uniformity. The steep slopes would then disappear, and the extreme differences would be reduced to comparatively small changes.

With this explanation the groups 4 and 5 should be altered: the dark line 448 of group 4 should stand by itself, and group 5 should contain the remaining three columns.

Of the other groups ‡ the following remarks from the observer's note-book are a necessary supplement to the columns of relative wave-lengths, which contain only the line or lines which could be followed safely with the micrometer.

Group 1 at λ 492.—Only one line, a dark one, of this group is entered in the tables. It has probably a bright companion on its red side, apparently always in the same position, and if it be a real line it differs from all the other radiations in keeping the same relative position as the absorption lines.

The group falls very near the red side limit of photographic sensibility, and required very careful attention. The absorption line is broad, nearly 5 tenth-metres in width. That it fades gradually during the first four days, and recovers in the last three, rests upon the percentage of certain, probable, and suspected positions for each day; and its weakness between days 5 and 10 inclusive is shown by its complete absence from twenty-eight out of thirty-three plates belonging to this interval: of the five exceptions only two show it as probable on July 6 and September 25; the remaining three are barely suspected.

It is possible that these exceptions may be due to some period of longer duration than that of the light changes; but it can hardly be doubted that the intensity of the absorption is mainly

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* *M.N.* vol. lvii. p. 7.

† *Mélanges Mathématiques et Astronomiques*, vol. vii. p. 427.

‡ In the original MS. the order of decreasing wave-lengths of the spectral lines was observed, both in the tables of figures and on the maps. It was decided to reverse the maps and the columns of figures for the press. But it was too late to re-arrange the text; and for this reason the numbers of the columns appear in the reverse order, from right to left.

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under some influence closely connected with the light period; and we have, so far, no clue to any longer period: for neither of the months, July or September, can be accepted as epochs of such a period, since of the twelve plates obtained in July and twenty-five in September there are no confirmations of the positive probable exceptions.

The radiation companion is also broad like the absorption, and appears to follow the same changes of intensity, inasmuch as it is noted only for the days of the first and last quarter of the period.

Group 2 at λ 486.—Of this group only bright H_3 is shown. It is broad and strong, with a fluctuating intensity, which may, at this part of the spectrum, be a photographic difficulty, but appearing strongest at the chief minimum. It is terminated on each side by a weak though broad absorption line; and of the two absorptions the blue side one is the stronger during the first half of the light period, and is strongest at the first maximum, while the other on the red side is stronger in the second half and strongest at the second maximum. This looks like the reverse of Belopolsky's observations of the same line. Here we seem to have a broader absorption cut in two by a less broad radiation, the two dark components alternately both widening and strengthening as the bright line shifts to the opposite side. But this interpretation can hardly be admitted, because on two plates between the chief minimum and first maximum we have the bright line noted as divided, with the red side component the narrower and weaker on August 22 and September 30, and two plates just after the first maximum on June 20 show a probable double with equal components.

Group 3 at λ 471.—The absorption line of this group appears clearly at the chief minimum, beginning, it would seem, at eight hours before and vanishing at the end of the second day after it. It is absent on all the intervening days if we may neglect its positions entered λ 470 as more probably belonging to another origin. It may be completely masked by the bright line during this interval, and only appear when the bright line is at its greatest red-side displacement. The bright line is notably wider with diffuse and hazy edges, shortly after the second minimum, when the two centres are together, and might be divided if the dark line were stronger. This appearance of a double bright line is noted as very probable on June 12, the ninth day of the period; and again on September 12, the tenth day, the components in each case being nearly equal, but that at the red side slightly the narrower and weaker. So far, therefore, the superposition hypothesis suits this group, but the changes of intensity do not favour it. The bright line is extremely weak near the principal minimum, and is quite extinct at the precise hour of the minimum; while it is strongest just after second minimum.

Groups 4 and 5.—Of these two groups, which have been

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already fully discussed as one group, it is only necessary to add that both the dark components appear to spring suddenly up to their strongest either at, or shortly before, the principal minimum, agreeing with Vogel's observation * of H_ζ. The extreme weakness of the absorption line 448 on day 5 is very remarkable. There are four good plates for this day, one taken in May, two in September, and one in October ; and it is only barely suspected on two out of the four.

Groups 6, 12, and 13 agree with group 3 in the extreme weakness of the radiation at the first minimum, but differ in being also very weak at and after the second minimum. But they show no signs of widening or dividing.

Group 7.—Both the radiation and absorption components of H_γ are very strong between the chief minimum and first maximum. The absorption is weaker during the second half of the period, and is very feeble at both minima. A weaker absorption on the red side of the hydrogen pair remains nearly constant throughout the period.

The radiation is nearly, if not quite, extinct at both minima. Its brightness fades continuously between the preceding maximum and the minimum phases, and recovers abruptly shortly after each minimum. These variations are in striking contrast with the comparatively constant radiation intensity of H_β. A careful re-examination of the best plates shows that this discordance between the two hydrogen lines cannot be attributed to the difference between the photographic sensibility at the two parts of the spectrum ; there is no appearance of over-exposure at the position of H_γ.

Group 8 at λ 423.—This absorption line, like that at λ 448, is quite extinct on day 5. No trace of it is found on the same four plates already quoted for the line 448 of group 4. A feeble radiation line has also been noted as probable or suspected on some of the plates belonging to the period from just before the first minimum to the first maximum, always on the red side of the absorption.

Group 9.—This appears always as a single absorption line, except on July 27, second day after first minimum, when there is probably a radiation companion on the red side ; and on two plates of June 30, just after first minimum, it appears unusually wide and probably divided.

Group 10.—A radiation line is noted as probable on the red side of this dark line on June 30 only, just after chief minimum. The absorption line has been noted as probably double on the following days :

Day 2, June 5.
„ 2, July 1, on two plates. Red side component wider.
„ 4, June 20. Both components equal.

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* A and A – P, 125, p. 363.

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Day 4, July 3. Red side component narrower.
„ 5, Sept. 20. „ „ „
„ 13, July 12. Blue side component very narrow and weak.

To conclude, we may ask and endeavour to answer the question: what has been added to our knowledge of this variable star since our first attempts upon its spectrum with the weaker light-power in 1893? If we confine our attention to our own observations the answer is ready, that we have neither more nor less than a confirmation of the conclusions stated in our report of the earlier work,* including the suggestion of tidal action as the cause of the bright line origins, and the claims for an elongated ellipse in place of a circular orbit. The exceptional absences of lines from plates which ought to show them if existent, at times when they usually appear, may be accounted for by the complex movements of more than two stars. They are more easily explained by the natural variations attending the periodic evolution of heat by tidal action at the periastron. The abrupt changes, both of intensity and position, at the chief minimum as compared with the slower changes at the secondary minimum are very significant; the velocity at the first must be greatly in excess of that at the second minimum, which is inconsistent with circular motion. The constancy of the spectrum, both in the strength and position of the lines, during the first quarter of the period beginning at the middle of the first day indicates, on the one hand, the first days of renewed heat energy, and, on the other, a sharp curve in the orbit at periastron, and the general weakness of the radiation lines in the latter half of the period is more in keeping with the cooling process of the bright line star than with the shading of superpositions. This view of the state of things with β *Lyræ* is at least not opposed to Belopolsky's conclusion: "En général il faut avouer que l'ensemble des faits, que l'on observe dans le spectre de cette étoile, est loin d'être expliqué par un mouvement des corps sur des orbites; il faudra toujours dans l'explication revenir aux procédés intérieurs." †

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* *M.N.* vol. liv. pp. 98-99.

† *Mélanges Mathématiques et Astronomiques*, vol. vii. p. 446.

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Wave-lengths and Intensities of Selected Groups in the Spectrum of β

Day Age from Principal Minimum.			13				12				11		10		9		8		7	
			Rad.		Abs.		Rad.		Abs.		Abs.		Abs.		Abs.		Abs.		Rad.	
			λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i
	d.	h.	40		40		41		41		41		41		41		42		43	
1	0	0			26	6			02	6	21	2	30	3	46	4	35	2		
	0	0			26	4			03	5	21	2	30	3	45	4	35	3		
	0	2			26	6			02	5	22	2	30	3	45	5	35	3	46	3
	0	11	–	–	25	6	s	–	01	8	21	2	31	3	44	3	35	3	47	10
	0	12	–	–	25	10	s	–	01	10	20	2	30	4	43	4	36	2	46	8
	0	22	29	4	25	10	05P	4	01	10	21	5	30	5	43	9	35	4	46	10
Means ...			29	1	26	7	05P	1	02	7	21	3	30	4	44	5	35	3	46	5
2	1	8	–	–	26	6	–	–	01	10	21	3	30	4	44	4	34	2	46	8
	1	9	30P	2	26	10	06P	2	02	10	22	2	31	3	44	3	35P	2	46	6
	1	9	–	–	26	8	–	–	02	10	21	2	31	4	45	4	34	2	45	3
	1	12	–	–	26	6	s	–	02	10	22	2	30	3	45	3	35	2	45	8
	1	12	–	–	26	10	s	–	01	10	22	3	31	4	44	4	34	3	45	6
	1	15	29P	2	25	9	05s	–	01	10	20	3	29	4	44	6	34	3	46	8
	1	18	29P	3	25	6	05P	2	00	10	20	3	29	4	44	5	33	4	45	10
	1	22	29P	2	26	8	05P	2	01	10	21	2	30	3	43	4	33	2	45	8
	1	23	29P	3	25	10	05P	2	01	10	20	2	30	3	43	4	34	2	45	8
Means ...			29P	2	26	8	05P	2	01	10	21	2	30	4	44	4	34	2	45	7
3	2	3	30s	–	26	6	06s	–	01	10	21	2	30	3	44	4	33	2	45	10
	2	5	30s	–	26	6	06s	–	01	10	20	2	29	3	43	4	35	1	46	10
	2	7	30s	–	26	5	05s	–	01	10	20	2	30	3	44	3	35	2	45	8
	2	8	29s	–	25	6	05s	–	01	10	20	2	30	3	43	3	33	1	45	10
	2	8	–	–	26	6	06s	–	02	10	21	2	30	1	43	2	35	2	46	10
	2	9	30s	–	26	6	06P	2	01	10	20	2	30	3	44	3	35	2	46	10
	2	10	29P	2	26	5	06s	–	01	10	20	2	30	2	44	3	35	2	45	8
Means ...			29P	2	26	6	06P	2	01	10	20	2	30	3	44	3	34	2	45	9
			40		40		41		41		41		41		41		42		43	

s = suspected } Excluded from means.
Dash = inconclusive }
i = intensity, 10 = the maximum.

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ı a series of Photographs obtained at Stonyhurst College Observatory.

6			5				4				3				2		1		Date, &c. 1895.
ıd.	Abs.		Rad.		Abs.		Rad.		Abs.		Rad.		Abs.		Rad.		Abs.		
i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	
	43		44		44		44		44		47		47		48		49		m. d. h.
	88	5			69	4	75	6	80	4			15	1	68	10	23	4	9 15 11¾, v.g.
	89	6			71	3	77	4	81	3	09s	–	–	–	68	10	26	4	9 28 10 ,,
	88	9			69	5	75	5	80	5			13	4	65	10	–	–	10 24 8 ,,
–	88	6			70	8	77	10	82	3	–	–	13	4	69	8	24	2	6 30 10-50 ,,
–	88	10			71	10	76	8	81	4	–	–	13	4	71	8	24	3	6 30 11-45 ,,
'2	88	10			70	10	76	10	80	4	21	3	13	4	69	10	26	9	9 29 8, perfect
'1	88	8			70	7	76	7	81	4	21	1	13	3	68	9	25	4	
–	87	9			69	10	75	10	78	4	19P	2	13	4	68	6	26	3	6 5 11¾, fair
'2	87	8			70	8	76	10	81	3	21	4	13	4	71	6	–	–	6 5 12½ ,,
–	88	5			69	4	75	6	79	4			12	2	69	4	27P	2	6 18 11, g.
–	88	5			70	6	76	10	79	4	18P	2	13	1	69	2	24P	2	7 1 12 ,,
–	87	4			70	6	75	10	79	2	19s	–	13s	–	69	2	24s	–	7 1 12 ,,
5	88	6			70	7	76	10	80	3	21P	2	15s	–	71	3	26	3	7 27 11 ,,
3	88	6			69	6	76	10	80	3	21P	2	15P	2	71	6	26	4	8 22 10, v.g.
2	87	4			69	5	75	6	78P	2	21	3	–	–	68	6	23	4	9 30 8, g.
–	88	4			70	4	76	10	78P	2	22	2	15	2	69	8	26	4	9 30 9, v.g.
3	88	6			70	6	79	3	76	9	20	2	14	3	69	5	25	3	
2	87	4			69	4	75	10	78P	2	18	2	13	2	68	6	23	3	10 26 9, v.g.
–	87	4			69	3	76	10	78s	–	21s	–			69	6	23	3	5 11 13 ,,
–	88	3			70	3	75	10	78s	–	17	6			69	4	24s	–	6 6 11 ,,
–	86	3			69	3	75	6	78s	–	–	–	–	–	68	4			6 6 11½, g.
2	88	3			70	3	75	10	80s	–	s	–	–	–	69	10	23s	–	6 6 11½, poor
2	88	3			70	3	76	10	78s	–	19P	2			69	6	–	–	6 19 11, fair
2	88	3			70	3	75	10	78s	–	19	4			71	4	–	–	6 19 11½, g.
2	87	3			70	3	75	9	78P	2	18	4			69	6	23	2	
	43		44		44		44		44		47		47		48		49		

P = probable.
Blank = no line.

Day Age from Principal Minimum.			13				12				11		10		9		8		7	
			Rad.		Abs.		Rad.		Abs.		Abs.		Abs.		Abs.		Abs.		Rad.	
			λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i
	d.	h.	40		40		41		41		41		41		41		42		43	
	3	7	29s	–	25	6	s	–	01	10	20	2	30	2	44	3	s	–	46	10
4	3	8	29s	–	25	4	05	10	01	10	20	2	28	3	42	4	s	–	46	10
	3	9	30	5	26	6	06	4	01	10	20	2	30	3	43	3	35P	2	46	10
	3	11	s	–	26	5	06P	2	01	10	20	2	30	4	43	4	34	2	46	6
	3	12	30s	–	25	5	s	–	02	10	20	2	29	3	43	3	s	–	46	6
	3	15	30s	–	25	6	06P	2	01	10	20	2	30	3	43	3	33s	–	46	8
	3	17	30	4	26	4	06	4	01	10	21	2	30	2	43	2	35	1	47	6
Means ...			30	5	25	5	06	4	01	10	20	2	30	3	43	3	35	2	46	8
5	4	6	30s	–	25	6	06	2	01	10	21	2	31	3	43	4			46	8
	4	20	30s	–	26	5	06	6	01	10	20	2	30	3	44	3			47	10
	4	20	30P	2	27	4	07	2	02	8	20	2	30	2	44	2			48	6
	4	23	29P	2	25	4	06	3	01	8	20	2	30	3	43	3			45	6
Means ...			30P	2	26	5	06	3	01	9	20	2	30	3	44	3			47	8
6	5	2			26	5			03	9	21	2	31	2	44	2	34	2	45	6
	5	11			26	5			01	9	20	2	30	3	44	3	34s	–	45	6
	5	18	–	–	25	2	s	–	01	–	–	–	–	–	–	–	–	–	46	4
	5	21	29P	2	26	5	06s	–	02	10	21	2	30	4	44	3	34	3	46	6
	6	0	30s	–	26	3	06s	–	01	8	21	2	30	3	44	3	33	2	47	7
Means ...			29P	1	26	4			02	9	21	2	30	3	44	3	34	2	46	6
	6	0	30s	–	26	3	06s	–	01	8	21	2	30	3	44	3	33	2	47	7
7	6	4	30s	–	26	4	06s	–	02	10	21	2	31	3	44	3	33	2	46	3
	6	11	–	–	25	3	–	–	02	6	20	2	30	2	44	2	34P	2	45	2
	6	12			25	2			01	2	20	2	30	2	43	2	–	–	46P	2
	6	12	30P	2	26	4			03	6	22	2	31	3	45	3	35	2	46s	–
	6	20			25	2			00	6	20	2	30	2	43	2	–	–		
Means ...			30P	1	26	3			02	6	21	2	30	3	44	3	34	2	46	3
			40		40		41		41		41		41		41		42		43	

s = suspected
Dash = inconclusive } Excluded from means.

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6				5				4				3				2		1		Date, &c. 1895.
Rad.		Abs.		Rad.		Abs.		Rad.		Abs.		Rad.		Abs.		Rad.		Abs.		
	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	
		43		44		44		44		44		47		47		48		49		m. d. h.
3	6	87	3			71P	2	75	10	79s	–	19	5			69	6	24	3	6 7 11¼, g.
3P	2	87	3			70s	–	75	10	78s	–	18	4			68	8	24	2	6 7 12 „
4s	–	88	3			71s	–	75	10	79s	–	–	–			69	8	–	–	6 20 10½, fair
3P	2	87	3			70P	2	75	10	79P	2	16s	–			71	5	26	3	7 3 10-40, g.
2s	–	87	2			s	–	75	8	–	–	–	–			71	5	–	–	7 3 11-40 „
2P	2	87	3			70	3	76	8	79	2					71	6	23	2	7 29 10½ „
2P	2	87	3			70s	–	76	6	79s	–	19	3			69	5	24P	2	8 24 9 „
3	3	87	3			70	2	75	9	79	2	19	3			70	6	24	2	
3s	–	86P	2			71s	–	76	6	80s	–	17	4			69	6			5 26 12, g.
2	6	87	4			71s	–	76	10	79s	–	18	6			69	10			9 20 8 „
s	–	87	2					76	10			16	6			68	10			9 7 10 „
2P	2	85	2					74	10			14	4			65	6			10 16 7 „
2	4	86	3					76	9			16	5			68	8			
3	3	88	2	s	–			74	10			16	5			67	8			5 1 13, v. g.
4s	–	88	2	71	6			75	10	80P	2	17	5			69	6			7 5 10-35, v.g.
–	–	–	–	69	8			74	9	–	–	17	4			67	3	–	–	9 8 8, v. poor
4P	2	88	3	69	7			75	10	80	3	17	6			68	10			10 4 7-25, v.g.
2	3	86	2	67	6			74	10	s	–	16	6			65	10			10 17 8 „
3	3	88	2	69	7			74	10	80	2	17	5			67	7			
2	3	86	2	67	6			74	10	s	–	16	6			65	10			10 17 8, v. g.
0s	–	87	2	68s	–			74	10	80	2	16	2			67	4			5 15 11¾ „
		87	1	72	10			76	10	80	2	16	6			68	3	–	–	7 6 11, poor
3s	–	88	2	68	10			74	10	79	2	17	5			67	4	23P	2	7 6 12, fair
3s	–	88	2	69	10			75	10	s	–	16	3			67	8			7 19 10-25, g.
		86s	–	67	10			73	10	78	2	10	2			62	9			9 22 8, g.
92	1	87	2	69	9			74	10	79	2	15	4			66	6			
3		43		44		44		44		44		47		47		48		49		

P = probable.
Blank = no line.

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Day Age from Principal Minimum.			13				12				11		10		9		8		7		
			Rad.		Abs.		Rad		Abs.		Abs.		Abs.		Abs.		Abs.		Rad.		
			λ	*i*	λ	*i*	λ	*i*	λ	*i*	λ	*i*	λ	*i*	λ	*i*	λ	*i*	λ	*i*	
	d.	h.	40		40		40		41		41		41		41		42		43		4
8	7	7			26	5			02	8	21	2	30	4	45	4	33	2	36s	–	
	7	8	–	–	26	3	–	–	02	10	22	2	30	4	45	2	s	–	36	–	
	7	9	–	–	26	2	–	–	02	8	21	2	30	5	45	2			36s	–	
	7	11	–	–	26	3	–	–	02	4	20	2	30	2	45	2	35	2	36s	–	
	7	12	–	–	25	4	–	–	01	6	20	2	29	3	44	3	33	2	s	–	
	7	15	–	–	25	4	–	–	01	10	22	2	30	4	44	4	35	3	36P	2	
	7	18	21	–	26	3	97s	–	02	8	22	2	30	3	44	3	34	2	36	4	
	7	21	22P	2	26	3	96P	2	01	4	21	2	30	3	44	2	34	2	36s	–	
	7	23	–	–	27	4	98s	–	03	10	23	2	32	3	45	3	35	2	36	5	
Means ...			22P	1	26	3	96P	1	02	8	21	2	30	3	45	3	34	2	36	4	
9	8	8	–	–	26	4			02	8	20	2	30	3	45	3	35	2	35	2	4
	8	11	–	–	–	–	96s	–	01	4	20	2	30	2	43	2	33P	2	35P	2	4
	8	14	21s	–	25	4	96s	–	01	10	21	2	30	4	43	3	33	2	33	2	4
Means ...					26	4			01	7	20	2	30	3	44	3	34	2	34	2	4
10	9	3	–	–	26	4	s	–	01	6	20	2	29	3	43	2	s	–	34	2	4
	9	19	–	–	–	–	–	–	01	10	21	2	30	2	43	2	33	2	33	2	4
	9	20	20s	–	25	2	95s	–	01	10	19	2	30	3	44	3	34	2	33	5	4
	9	21	20s	–	26	4	95s	–	01	8	21	2	29	2	43	2	33	2	33	3	4
	9	21	20P	2	25	2	96s	–	01	10	21	2	30	3	44	3	33	2	34	3	4
	9	23	21s	–	27	3	94s	–	02	8	21	2	31	2	43	2	34	2	33	3	4
Means ...			20P	2	26	3			01	9	21	2	30	3	43	2	33	2	33	3	4
11	10	9	19s	–	25	4	94s	–	01	10	20	2	31	2	44	2	35P	2	33P	2	4
	10	18	19	2	24	4	94P	2	01	7	21	2	29	3	43	3	s	–	33P	2	4
	10	21	19s	–	25	4	96s	–	01	8	20	2	30	2	43	2			34	3	4
	10	22	21P	2	25	6	96s	–	01	8	20	2	30	2	44	2	33P	2	35	2	4
	10	23	–	–	–	–	–	–	03	6	21	2	30	2	44	2	s	–	34s	–	4
	10	23	–	–	25	3	–	–	03	10	22	2	31	2	45	2	34	2	36	2	4
Means ...			20P	2	25	4	94P	2	02	8	21	2	30	2	44	2	34P	2	34	2	4
			40		40		40		41		41		41		41		42		43		43

s = suspected
Dash = inconclusive } Excluded from means.

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6		5				4				3				2		1		Date, &c. 1895.
Abs.		Rad.		Abs.		Rad.		Abs.		Rad.		Abs.		Rad.		Abs.		
λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	
43		44		44		44		44		47		47		48		49		m. d. h.
87P	2	66	10			72	10	78	3	06	6			58	9	s	–	6 11 11, g.
87	2	66	10			73	10	78	3	09	6			58	10			6 11 12 ,,
88	2	67	10			74	10	79	2	11	6			62	6			6 24 11, fair
87	2	68	10			74	10	79	2	11	5			62	8			7 7 10–35, g.
85	2	66	10			73	10	78	2	09	4			60	9			7 7 12, g.
87	2	66	6			74	6	79	3	09	4	01P	2	61	6			8 11 1 ,,
87	2	67	9			74	9	79	3	12	5	05s	–	62	8			9 10 8, v. g.
87	2	65	8			73	8	79	2	12	4			60	10			9 23 9 ,,
88	2	66	10			73	10	80	2	13	6			62	9			10 19 7 ,,
87	2	66	9			73	9	79	2	10	5			61	8			
87	2	66	5			73	5	79	2	10	5			55	6			6 12 $11\frac{3}{4}$, v. g.
86	2	64	5			73	5	78	3	11	4			55	4			6 25 13, poor
86	2	66	3			73	3	78	2	06	4	00	2	58	4			7 21 12, fair
86	2	65	4			73	4	78	2	09	4			56	5			
87	1	62	2			71	2	77	2	06	3			50	5			5 18 $11\frac{1}{4}$, g.
												46						
86	2	62	5			68	5	77	4	05	3	97P	2	53	4			9 12 9, g.
86	2	62	4			70	4	78	2	06	3	98P	2	54	10	s	–	9 25 8, v. g.
86	2	61	5			69	5	78	2	05	5	97P	2	53	10			9 12 11, g.
85	3	60	4			70	4	77	3	01	2	s	–	55	6	24P	2	9 25 9, v. g.
86	2	62	2			71	2	77	2	04	2			53	6			10 8 9, g.
86	2	62	4			70	4	77	3	05	3			53	7	24P	1	
87	4	63P	3	67s	–	74s	–	78s	–	04s	–			54	6	–	–	6 27 $10\frac{1}{2}$, v.g.
85	3	60	4	64	2	69	4	76	2	04	4	97s	–	53	10	20P	2	9 13 8 ,,
86	3	61	3	67P	2	73	3	78P	2	05s	–			55	4	26P	2	9 13 11 ,,
85	2	61	2	66	2	72	2	77	2					57	4	24s	–	9 26 10, g.
87	2	–	–	68s	–	s	–	79	2	–	–			57	4	29P	2	9 26 11 ,,
86	3	62P	2	67	3	72P	2	78	3	05	3			54	5	23P	2	10 22 7, v.g.
86	3	61	3	66	2	72	3	78	2	05	2			55	6	25P	2	
43		44		44		44		44		47		46		48		49		

P = probable.
Blank = no line.

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	Day Age from Principal Minimum.	13				12				11		10		9		8		7		
		Rad.		Abs.		Rad.		Abs.		Abs.		Abs.		Abs.		Abs.		Rad.		
		λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	
		40		40		41		41		41		41		41		42		43		
12	11 8			26	6			01	10	22	2	30	4	44	4	34	2	35s	–	
	11 8	21s	–	26	4	96s	–	01	8	22	2	30	3	45	3	34	2	35P	2	
	11 9			26	4			01	8	20	3	30	4	45	3	–	–	s	–	
	11 9			26	4			01	10	20	2	29	3	43	3	33	2	31	2	
	11 19			25	3			01	7	20	2	30	2	44	2	33s	–			
	11 20			26	4	94P	2	01	6	20	2	30	2	43	2	s	–			
	11 21	20s	–	26	4	s	–	02	7	21	2	30	2	45	3	33	2			
	11 21	21P	2	25	5	s	–	01	10	20	2	30	3	44	3	33	2			
	11 23			26	3			02	6	21	2	31	3	44	3	s	–	35P	2	
Means ...				26	4			01	8	21	2	30	3	44	3	33	2	34P	1	
13	12 7			25	7			01	10	20	2	30	4	43	4	33	2	34s	–	
	12 8			25	7			02	10	22	2	30	4	45	4	34	2	s	–	
	12 10			26	5			02	8	21	2	30	3	44	3	33	2	34P	2	
	12 11			25	4			02	6	22	2	31	3	44	3	34	2	s	–	
	12 12			25	4			02	6	21	2	30	4	45	3	34	2	s	–	
	12 14	18s	–	26	6	95s	–	01	10	21	2	30	4	45	4	35	3	35P	2	
	12 17	s	–	26	8	s	–	02	8	22	2	30	3	45	4	34	2			
	12 19			26	5			02	6	22	2	31	3	45	3	s	–			
	12 20			26	5			01	6	22	2	30	2	44	2	33	2			
	12 21			27	6			02	6	22	2	32	3	45	3	35	1			
	0 0			26	6			02	6	21	2	30	3	46	4	35	2			
Means ...				26	6			02	7	21	2	30	3	45	3	34	2	35P	1	
		40		40		41		41		41		41		41		42		43		4

s = suspected
Dash = inconclusive } Excluded from means.

		5				4				3				2		1		
Abs.		Rad.		Abs.		Rad.		Abs.		Rad.		Abs.		Rad.		Abs.		Date, &c.
λ	*i*	λ	*i*	λ	*i*	λ	*i*	λ	*i*	λ	*i*	λ	*i*	λ	*i*	λ	*i*	1895.
43		**44**		**44**		**44**		**44**		**47**		**46**		**48**		**49**		m. d. h.
87	3	–	–	68	4	s	–	78	3	s	–	s	–	55	2	24	2	6 15 12, g.
86	4	63P	2	69	4	74P	2	79	2			s	–	54	4	24P	2	6 15 11½ ,,
87	3			68	4			80	3	04P	2	96P	2	57	2			6 15 12¾ ,,
87	3	–	–	66	2	s	–	78	2	05P	2			53	3	s	–	6 15 13¼, v.g.
86	3			69	4			80	3	07s	–	99s	–	62s	–			9 27 7, g.
87	3	60P	2	68	7			79	3					60	4	21P	1	9 27 8 ,,
87	4			69	8			79	4					58	5	21	4	9 27 9, v.g.
86	4			68	8			79	4	s	–	s	–	55	5	20s	–	10 10 7, g.
86	3	62P	2	67	10	74P	2	78	3	04s	–	97s– **47** 09s–		54	3	23	2	10 23 7, v.g.
87	3	62P	1	68	6	74P	1	79	3	05P	1			56	4	23	2	
85	4	63P	2	68	3	74P	2	78	3			–	–	58	9	21	4	6 16 10½, v.g.
87	5			69	3			80	3	21P	2	s	–	60	6	21	4	6 16 11½ ,,
87	4	s	–	68	3	s	–	79	3	22P	2	s	–	60	4	23	3	7 12 10-25, v.g.
87	3	s	–	68	3	s	–	79	3					61	9	21	4	7 12 10-40, g.
87	5	s	–	68	2	74P	2	79	2	s	–			60	10	24	3	7 12 11-40, v.g.
87	5	64P	2	69	5	75P	2	79	5	s	–	13	3	64	9	24	4	8 7 10, v.g.
89	6			70	3			81	3	s	–	15	2	65	10	24	4	9 2 9, g.
88	6	64s	–	70	3	76P	2	81	3			13	2	65	10	24	4	9 15 8¾, v.g.
87	5	–	–	68	3	74	4	79	3	18s	–	13	2	64	10	20	2	9 15 10, poor.
89	4	64P	2	70	3	76	4	80	3			13	3	65	10	24	3	9 15 11-15, v.g.
88	5			69	4	75	6	80	4			15	1	68	10	23	4	9 15 11¾ ,,
87	5	64P	1	69	3	75	2	80	3	22P	1	14	2	63	9	23	4	
43		**44**		**44**		**44**		**44**		**47**		**47**		**48**		**49**		

P = probable.
Blank = no line.

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Spectrum of β Lyræ, 1895, *Stonyhurst College Observatory.*

	13				12				11		10		9		8			
Day Age.	Rad.		Abs.		Rad.		Abs.		Abs.		Abs.		Abs.		Abs.		Rad.	
	λ	*i*	λ	*i*	λ	*i*	λ	*i*	λ	*i*	λ	*i*	λ	*i*	λ	*i*	λ	*i*
	40		40		41		41		41		41		41		42		43	
1	29	1	26	7	05P	1	02	7	21	3	30	4	44	5	35	3	46	5
2	29P	2	26	8	05P	2	01	10	21	2	30	4	44	4	34	2	45	7
3	29P	2	26	6	06P	2	01	10	20	2	30	3	44	3	34	2	45	9
4	30	5	25	5	06	4	01	10	20	2	30	3	43	3	35	2	46	8
5	30P	2	26	5	06	3	01	9	20	2	30	3	44	3			47	8
6	29P	1	26	4			02	9	21	2	30	3	44	3	34	2	46	6
7	30P	1	26	3			02	6	21	2	30	3	44	3	34	2	46	3
8	22P	1	26	3	40 96P	1	02	8	21	2	30	3	45	3	34	2	36	4
9			26	4			01	7	20	2	30	3	44	3	34	2	34	2
10	20P	2	26	3			01	9	21	2	30	3	43	2	33	2	33	3
11	20P	2	25	4	94P	2	02	8	21	2	30	2	44	2	34P	2	34	2
12			26	4			01	8	21	2	30	3	44	3	33	2	34P	1
13			26	6			02	7	21	2	30	3	45	3	34	2	35P	1
	40		40		40		41		41		41		41		42		43	
Range	10	4	1	5	12	3	1	4	1	1	0	2	2	3	2	1	14	8

e-lengths and Intensities of the Selected Groups for each Day Age.

	6		5				4				3				2		1		
	Abs.		Abs.		Rad.		Rad.		Abs.		Rad.		Abs.		Rad.		Abs.		No. of Plates
	λ	*i*	λ	*i*	λ	*i*	λ	*i*	λ	*i*	λ	*i*	λ	*i*	λ	*i*	λ	*i*	
	43		44		44		44		44		47		47		48		49		
	88	8	70	7			76	7	81	4	21	1	13	3	68	9	25	4	6
	88	6	70	6			76	9	79	3	20	2	14	3	69	5	25	3	9
	87	3	70	3			75	9	78P	2	18	4			69	6	23	2	7
	87	3	70	2			75	9	79	2	19	3			70	6	24	2	7
	86	3					76	9			16	5			68	8			4
	88	2			69	7	74	10	80	2	17	5			67	7			5
	87	2			69	9	74	10	79	2	15	4			66	6			6
	87	2			66	9	73	9	79	2	10	5			61	8			9
	86	2			65	4	73	4	78	2	09	4			56	5			4
	86	2			62	4	70	4	77	3	05	3			53	7	24P	1	5
	86	3	66	2	61	3	72	3	78	2	05	2			55	6	25P	2	6
	87	3	68	6	62P	1	74P	1	79	3	05P	1			56	4	23	2	9
	87	5	69	3	64P	1	75	2	80	3	22P	1	14	2	63	9	23	4	11
	43		44		44		44		44		47		47		48		49		
3	2	6	4	5	8	8	6	9	4	2	18	4	1	1	16	5	2		

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